Mining and Quarrying

(SIC 10, 12 and 14)

SIGNIFICANT POINTS

- Technological innovations, environmental regulations, and international competition will continue to reduce employment in mining and quarrying.
- Most production jobs require little or no formal education or training beyond high school.
- Earnings are higher than average.

Nature of the Industry

Throughout history, mining has played an important part in the development of the United States. In the past, the discovery of minerals such as gold and silver has resulted in population shifts and economic growth. Extraction of minerals, such as coal and copper, continues to provide the foundation for the local economy in some parts of the country. Products of this industry are used as inputs for products, processes, and services provided by all other industries, including agriculture, manufacturing, transportation, communications, and construction. Such uses include coal for energy, copper for wiring, gold in satellites and sophisticated electronic components, and a variety of other minerals used as ingredients in medicines and household products.

Besides the mining and quarrying of coal and metallic and nonmetallic minerals, employers in this industry explore for minerals and develop new mines and quarries. *Metallic minerals* include ores, such as bauxite—from which aluminum is extracted—copper, gold, iron, lead, silver, and zinc. *Nonmetallic minerals* include stone, sand, gravel, clay, and other minerals such as lime and soda ash used as chemicals and fertilizers. This industry also includes initial mineral processing and preparation activities, because processing plants usually operate together with mines or quarries as part of the extraction process. A separate section in the *Career Guide* covers careers in oil and gas extraction.

Mining is the process of digging into the earth to extract naturally occurring minerals. There are two kinds of mining, *surface mining* and *underground mining*. Surface mining, also called open pit mining or strip mining, is undertaken if the mineral is near the earth's surface. This method is usually more cost efficient and requires fewer workers to produce the same quantity of ore as underground mining. In surface mining, after blasting with explosives, huge earthmoving equipment, such as power shovels or draglines, scoops off the layers of soil and rock covering the mineral bed. Once the mineral is exposed, smaller shovels lift it from the ground and load it into trucks. The mineral can also be broken up using explosives, if necessary. In quarrying operations, workers use machines to extract stone for use primarily as building material. Stone, such as marble, granite, limestone and sandstone, is quarried by splitting blocks of rock from a massive rock surface.

Underground mining is employed when the mineral deposit lies deep below the surface of the earth. When developing an underground mine, miners first must dig two or more openings, or tunnels, deep into the earth near the place where they believe coal or minerals are located. Depending on where the vein of ore is in relation to the surface, tunnels may be vertical, horizontal, or sloping. One opening allows the miners to move in and out of the mine with their tools, and also serves as an opening to transport the mined rock by small railroad cars or by conveyor belt to the surface. The other opening is used for ventilation. Miners remove the mineral from the bed, load it on the railroad cars or conveyor belts, and then haul it out of the mine through the other opening, or tunnel.

Entries are constructed so that miners and equipment can get to the ore and carry it out, while allowing fresh air to enter the mine. Once underground at the proper depth, a mine's tunnels interconnect with a network of passageways going in many directions. Long steel bolts and pillars of unmined ore support the roof of the tunnel. Using the room-and-pillar method, miners remove half of the ore as they work the ore seams from the tunnel entrance to the edge of the mine property, leaving columns of ore to support the ceiling. This process is then reversed, and the remainder of the ore is extracted, as the miners work their way back out. In the case of longwall mining of coal, self-advancing roof supports, made of hydraulic jacks and metal plates, are moved ahead, allowing the ceiling in the mined area to cave in as the miners work back towards the tunnel entrance.

During the 1980s and early 1990s, production of both metal and nonmetallic minerals increased. Given its more volatile price, metal production fluctuated more than that of nonmetallics. However, employment in both sectors declined significantly, as new technology and more sophisticated mining techniques increased productivity, allowing growth in output while employing fewer workers.

During this period, production of coal also increased, mainly as a result of increasing electric utility demand. Coal accounts for about one-third of overall domestic energy production and over half of U.S. electrical power was generated by burning coal in 1996. However, technological advancements in the U.S. coal industry, including larger, more powerful machinery and equipment; the use of new mining techniques; and the development of large surface mines, continue to reduce employment in coal mines.

Working Conditions

The average worker in the mining and quarrying industry worked 44 hours a week in 1998. Work environments vary by occupation. Scientists and technicians work in office buildings and laboratories, miners and mining engineers spend much of their time in the mine.

Working conditions in mines and quarries can be unusual and sometimes dangerous. Underground mines are damp and dark, and some can be very hot. At times, several inches of water may cover tunnel floors. Although underground mines have electric lights, only the lights on miners' caps illuminate many areas. Workers in mines with very low roofs may have to work on their hands and knees, backs, or stomachs in confined spaces. In underground mining operations, dangers include the possibility of an explosion or cave-in, electric shock, or exposure to harmful gas.

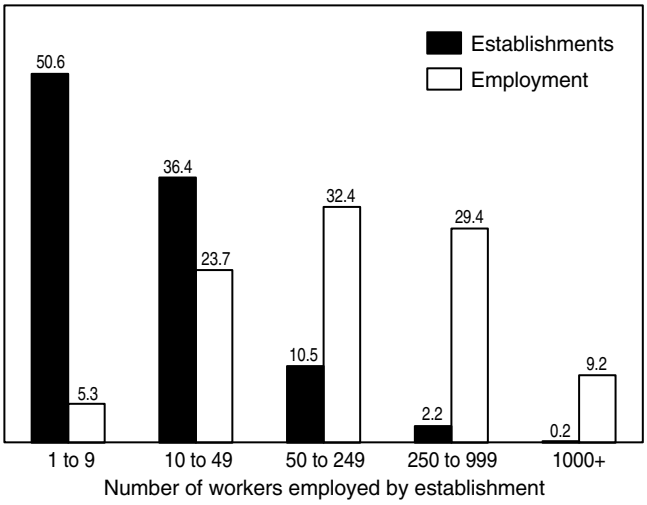
Workers in surface mines and quarries are subject to rugged outdoor work in all kinds of weather and climates. Physical strength and stamina are necessary, because the work involves lifting, stooping, and climbing. Surface mining, however, usually is less hazardous than underground mining.

In 1997, the rate of work-related injury and illness was 4.9 per 100 full-time workers in metal mining, 4.7 in nonmetallic minerals, and 7.8 in coal mining, compared with 7.1 for the entire private sector. Although mine health and safety conditions have improved dramatically over the years, dust generated by drilling in mines still places miners at risk of developing either of two serious lung diseases: pneumoconiosis, called "black lung disease," from coal dust, or silicosis from rock dust. The Federal Coal Mine Health and Safety Act of 1969 regulates dust concentrations in coal mines, and respirable dust levels are closely monitored. Dust concentrations in mines have declined as a result. Underground miners are now required to have their lungs x rayed when starting a job, with a mandatory follow-up x ray 3 years later, in order to monitor any development of respiratory illness. Additional x rays are given every 5 years on a voluntary basis. Workers who develop black lung disease or silicosis may be eligible for Federal aid.

Employment

There were approximately 251,000 wage and salary jobs in the mining and quarrying industry in 1998; around 92,000 in coal mining; 50,000 in metal mining; and 109,000 in nonmetallic mineral mining. According to the Energy Information Administration, there were around 1,800 coal mining operations in 25 States in 1997. Over half of U.S. coal is produced in three states: Kentucky, Wyoming, and West Virginia. Metal mining is more prevalent in the West and Southwest, particularly in Arizona, Colorado, Nevada, New Mexico, and Utah. Nonmetallic mineral mining is the most widespread, as quarrying of nonmetallic minerals, such as stone, clay, sand, and gravel, is done in nearly every State. About 50 percent of mining and quarrying establishments employ fewer than 10 workers (chart).

About 50 percent of mining and quarrying establishments employ fewer than 10 workers



Source: U.S. Department of Commerce, *County Business Patterns*, 1997

Occupations in the Industry

The mining and quarrying industry requires many kinds of workers. In 1998, almost 4 out of 5 workers were in *precision production, craft, and repair* or *operator, fabricator, and laborer* occupations (table 1).

Mining occupations. The majority of jobs in the mining and quarrying industry are in equipment operation and skilled craft and repair occupations. Though most of these jobs can be entered directly from high school, or after acquiring some experience and on-the-job training in an entry-level position, the increasing sophistication of equipment and machinery used in mining means a higher level of technical skill may now be required for many positions.

Underground mining primarily includes three methods: Conventional, continuous, and longwall mining. Conventional mining, which is being phased out, is the oldest method, requiring the most workers and procedures. In this method, a strip or "kerf" is cut underneath the ore seam to control the direction in which the ore falls after it has been blasted. *Cutting machine operators* use a huge electric chain saw with a cutter from 6 to 15 feet long to cut the kerf. Next, *drilling machine operators* drill holes in the ore where the *shot firers* place explosives. This potentially dangerous work requires workers to follow safety procedures, such as making sure everyone is clear of the area before the explosives are detonated. After the blast, *loading machine operators* scoop up the material and dump it into small rubber-tired cars run by *shuttle car operators*, who bring the coal or ore to a central location for transportation to the surface.

The continuous mining method eliminates the drilling and blasting operations of conventional mining by using a machine called a continuous miner. Traditionally, a c*ontinuous mining machine operator* sits or lies in a machine's cab and operates levers that cut or rip out ore and load it directly onto a conveyor or shuttle car. However, the use of remote-controlled continuous mining machines—which have increased safety considerably—now allows an operator to control the machine from a distance.

In longwall mining, which is similar to continuous mining, *longwall machine operators* run large machines with rotating drums that automatically shear and load ore on a conveyor. At the same time, hydraulic jacks reinforce the roof of the tunnel. As ore is cut, the jacks are hydraulically winched forward, supporting the roof as they move along.

Many other workers are needed to operate safe and efficient underground mines. Before miners are allowed underground, a *mine safety inspector* checks the work area for such hazards as loose roofs, dangerous gases, and inadequate ventilation. If

safety standards are not met, the inspector prohibits the mine from producing until conditions are made safe. *Rock-dust machine operators* spray the mine walls and floor to hold down dust which can interfere with breathing.

Roof bolters operate the machines that automatically install roof support bolts to prevent roof cave-ins, the biggest cause of mining injuries. *Brattice builders* construct doors, walls, and partitions in tunnel passageways to force air into the work areas. *Shift bosses*, or *blue-collar worker supervisors*, oversee all operations at the work site.

In surface mining, most miners operate huge machines that either remove the earth above the ore deposit, or dig and load the ore onto trucks. The number of workers required to operate a surface mine depends on the amount of overburden, or earth, above the ore seam. In many surface mines, the overburden is first drilled and blasted. *Overburden stripping operators* or *dragline operators* then scoop the earth away to expose the coal or metal ore. Some draglines are among the largest land machines on earth.

Next, *loading machine operators* rip the exposed ore from the seam and dump it into trucks to be driven to the preparation plant. *Tractor operators* use bulldozers to move earth and ore and to remove boulders or other obstructions. *Truckdrivers* haul ore to railroad sidings or to preparation plants, and transport supplies to mines.

Craft and *repair occupations.* Other workers, who are not directly involved in the extraction process, work in and around mines and quarries. For example, skilled *mechanics* are needed to repair and maintain the wide variety of mining machinery, and skilled *electricians* are needed to check and install electrical wiring. Mechanical and electrical repair work has become increasingly complex, as machinery and other equipment have become computerized. *Carpenters* construct and maintain benches, bins, and stoppings (barricades to prevent air flow through a tunnel). These workers generally need specialized training to work under the unusual conditions in mines. Mechanics, for example, may have to repair machines while on their knees with only their headlamps to illuminate the working area.

Quarrying occupations. Workers at quarries have duties similar to miners. Using jackhammers and wedges, *rock splitters* remove pieces of stone from a rock mass. *Dredge operators* and *dipper tenders* operate power-driven dredges, or dipper sticks of dredges, to mine sand, gravel, and other materials from beneath the surface of lakes, rivers, and streams. Using power-driven cranes with dragline buckets, *dragline operators* excavate or move sand, gravel, and other materials.

Processing plant occupations. Processing plants often are located next to mines or quarries. In these plants, rocks and other impurities are removed from the ore, which is then washed, crushed, sized, or blended to meet buyer specifications. Methods for physically separating the ore from surrounding material also include more complex processes, such as leaching—mixing the ore with chemical solutions or other liquids in order to separate materials. Most processing plants are highly mechanized and require only a few workers for the washing, separating and crushing operations. *Processing plant supervisors* oversee all operations. In plants that are not heavily mechanized, *wash box attendants* operate equipment that sizes and separates impurities from ore, and *shake tenders* monitor machinery that further cleans and sizes ore with a vibrating screen. Most jobs in the processing plant are repetitive and, as a result of highly computerized mechanization, are becoming more automated.

Table 1. Employment of wage and salary workers in mining and quarrying by occupation, 1998 and projected change, 1998-2008

(Employment in thousands)

Occupation	1998 Employment Number	1998 Employment Percent	1998-2008 Percent change
All occupations	250	100.0	-23.2
Precision production, craft, and repair	111	44.4	-25.1
Mining, quarrying, and tunneling occupations	22	8.8	-19.5
Blue-collar worker supervisors	17	6.6	-26.6
Industrial machinery mechanics	15	5.8	-25.8
All other extraction and related workers	14	5.4	-25.2
Grader, bulldozer, and scraper operators	11	4.5	-29.2
Mobile heavy equipment mechanics	6	2.5	-24.8
Maintenance repairers, general utility	5	2.1	-25.9
Electricians	4	1.8	-30.0
Operating engineers	2	1.0	-20.9
Operators, fabricators, and laborers	87	34.7	-19.3
Truckdrivers	22	8.7	-18.4
Helpers, laborers, and material movers, hand	15	5.6	-25.4
All other material moving equipment operators	12	4.6	-25.8
Excavation and loading machine operators	11	4.5	-13.8
Crushing, grinding, mixing, and blending machine operators and tenders	9	3.5	4.6
Welders and cutters	4	1.6	-25.0
Industrial truck and tractor operators	3	1.3	-21.3
Separating, filtering, clarifying, precipitating, and still machine operators and tenders	2	0.7	-25.0
Administrative support, including clerical	19	7.6	-25.6
General office clerks	4	1.4	-16.1
Bookkeeping, accounting, and auditing clerks	3	1.1	-33.6
Secretaries	3	1.0	-37.2
Weighers, measurers, checkers, and samplers, recordkeeping	2	0.9	-18.1
Executive, administrative, and managerial	19	7.6	-26.3
General managers and top executives	6	2.2	-22.2
Management support occupations	4	1.7	-27.4
Professional specialty	7	2.7	-24.3
Engineers		1.5	-25.5
Geologists, geophysicists, and oceanographers	1	0.4	-28.6
Technicians and related support	4	1.7	-28.6
Engineering and science technicians	4	1.5	-27.4
All other occupations	4	1.4	-23.0

Managerial, professional, technical, and *administrative support occupations*. Administrative workers include *general managers* and *top executives*, who are responsible for making policy decisions. Staff specialists (such as *accountants*, *attorneys*, and *market researchers*) provide information and advice for policymakers.

Professional and technical workers in mining and quarrying include engineering, scientific, and technical personnel. *Geologists* and *geophysicists* search for locations likely to yield coal or mineral ores in sufficient quantity to warrant extraction costs. *Mining engineers* examine seams for depth and purity, determine the type of mine to build, and supervise the construction, maintenance, and operation of mines. *Mechanical engineers* oversee the installation of equipment, such as heat and water systems; *electrical engineers* oversee the installation and maintenance of electrical equipment; *civil engineers* oversee the building and construction of mine sites, plants, roads, and other infrastructure; and *safety engineers* direct health and safety programs. Using sophisticated technologies and equipment, such as the Global Positioning System (GPS)—a satellite system that locates points on the earth using radio signals transmitted by satellites—*surveyors* help map areas for mining.

Environmental engineers and *scientists* play an increasingly important role in mining and quarrying, given environmental concerns and stringent Federal, State, and local regulations imposed on all operations. Restrictions imposed by environmental regulations make obtaining permits for new mine development projects increasingly difficult. Mine owners and operators face substantial penalties should they fail to abide by current regulations. In addition, both State laws and Federal regulations, such as the Surface Mining Control and Reclamation Act (SMCRA), require that land reclamation be part of the mining process. Reclamation plans must usually be approved by both government officials and local interest groups. When a mining operation is closed, the land must be restored to its premine condition, which can include anything from leveling soil and removing waste to replanting vegetation.

Exploration, mine design, impact assessment, and restoration efforts can depend on computer analysis. In addition, rapid technological advancements, particularly in processing plant operations, are the result of increased computerization. This has led to a growing reliance on professionals with computer skills, such as *systems analysts* and *computer scientists*.

Training and Advancement

Workers in mining and quarrying production occupations must be at least 18 years old, in good physical condition, and able to work in confined spaces. A high school diploma is not necessarily required. Most workers start as helpers to experienced workers and learn skills on the job; however, formal training is becoming more important, as more technologically advanced machinery and mining methods are used. Some employers prefer to hire recent graduates of high school vocational programs in mining or graduates of junior college or technical school programs in mine technology. Such programs usually are only found at schools in mining areas.

Mining companies may also offer formal training in either classrooms or training mines for a few weeks before new miners actually begin work. At mines covered by contracts with the United Mine Workers of America (UMWA), workers receive employer-sponsored pre-service instruction and annual retraining sessions in subjects such as machine operation, first aid, and health and safety regulations. All miners receive annual retraining instruction in all aspects of their job concerning health and safety. The U.S. Mine Safety and Health Administration conducts classes on health, safety, and mining methods; and some mining machinery manufacturers also offer courses in machine operation and maintenance.

As production workers gain more experience, they can advance to higher-paying jobs requiring greater skill. A mining machine operator's helper, for example, may become an operator. When vacancies occur, announcements are posted and all qualified workers can bid for the job. Positions are filled on the basis of seniority and ability. Miners with significant experience or special training can also become mine safety inspectors. According to the U.S. Mine Safety and Health Administration, an inspector needs, in general, at least 5 years experience as a miner, or a degree in mining engineering.

For professional and managerial positions in mining and quarrying, a bachelor's degree in engineering, one of the physical sciences, or business administration is preferred. A number of colleges and universities have mining schools or departments and programs in mining or minerals. Environmental positions require regulatory knowledge and a strong natural science background, or a background in a technical field, such as environmental engineering or hydrology. To date, most environmental professionals have been drawn from the ranks of engineers and scientists who have had experience in the mining and quarrying industry.

Universities and mining schools have introduced more environmental course work into their programs, and mining and quarrying firms are hiring professionals from existing environment-related disciplines and training them to their companies' needs. Additionally, specialized mine technology programs are available from a few colleges. Enrollment in these programs can lead to a certificate in mine technology after 1 year, an associate degree after 2 years, or a bachelor's degree after 4 years. Courses cover areas such as mine ventilation, roof bolting, and machinery repairs.

Earnings

Average earnings in mining and quarrying were significantly higher than the average for all industries. In 1998, production workers in coal mining averaged $19.16 an hour; workers in metal mining averaged $18.25 an hour; and workers in nonmetallic minerals mining averaged $14.72 an hour (table 2). Workers in underground mines spend time traveling from the mine entrance to their working areas, so their paid workday is slightly longer than that of surface mine workers, 8 hours versus 7-1/4-hour shifts. Workers in underground mines also tend to earn more per hour than miners on the surface. Earnings in selected occupations in selected mining and quarrying industries appear in table 3.

Table 2. Average earnings of nonsupervisory workers in mining and quarrying, 1998

Industry segment	Weekly	Hourly
Total, private industry	$442	$12.77
Coal mining	858	19.16
Metal mining	812	18.25
Nonmetallic mineral mining	683	14.72

Around 26 percent of mine workers are union members or are covered by union contracts, compared to about 15 percent of workers throughout private industry. About 30 percent of workers in coal and metal mining were union members in 1998, compared to about 22 percent of workers in nonmetallic mineral mining. Union coal miners are primarily represented by the UMWA. The United Steelworkers of America, the International Union of Operating Engineers, and other unions also represent miners.

Workers covered by UMWA contracts receive 11 paid holidays, 14 days of paid vacation each year, and 5 days of personal or sick leave; however, coal miners generally must take their vacations during one of three regular vacation periods, to assure a continuous supply of coal. As length of service increases, UMWA miners get up to 13 extra vacation days after 18 years of continuous employment. Union workers also receive benefits from a welfare and retirement fund.

Table 3. Median hourly earnings of the largest occupations in coal mining and nonmetallic minerals, except fuels, 1997

Occupation	Coal mining	Nonmetallic minerals, except fuels	All industries
Grader, bulldozer, and scraper operators	$16.87	—	$12.62
Excavating and loading machine operators	—	$11.58	12.77
Crushing, grinding, mixing, and blending machine operators and tenders	—	11.36	10.85
Truck drivers, heavy or tractor-trailer	—	10.95	13.08

Outlook

Employment in mining and quarrying is expected to decline by about 23 percent through the year 2008. This continuing long-term decline is due, in part, to increased productivity, resulting from technological changes in mining operations, as well as factors such as stringent environmental regulations and international competition.

Declining employment will be led by a decline in the coal mining sector. The products of the coal mining industry are used to produce electricity and steel products. Although production of coal is expected to increase, employment should continue to decline, as more efficient and automated production operations require less labor. Advances in longwall and surface mining, which are less labor-intensive, have increased productivity, as have improvements in transportation and processing. Additionally, innovations such as roof bolting, self-advancing roof supports, and continuous mining machinery have led to safer, more efficient operations.

The long-term outlook for coal also depends on how electric utility companies—the major consumers of coal—respond to provisions of the Clean Air Act Amendments of 1990, which attempt to limit the emission of sulfur dioxide and other harmful pollutants. Phase I of the Amendments, which took affect in 1995, requires reductions in sulfur emissions from coal combustion. Compliance involves the installation of costly cleaning and monitoring equipment or increased use of low-sulfur coal. Already, low transportation costs and rising demand for cleaner-burning coal have resulted in regional shifts in coal production and markets. Because of this, lower-sulfur Western coal now accounts for an increasing share of output. Improvements in clean coal technologies may help the industry cope with increasingly restrictive regulations through projects like the Integrated Gasification Combined Cycle (IGCC). This technology combines traditional coal gasification with gas turbine and steam power to generate electricity more efficiently and reduce carbon and sulfur dioxide emissions. Additional options include switching to other fossil fuels, or trading or selling "emission credits" among companies trying to meet standards. Though coal remains an abundant energy source, the coal mining industry will have to contend with environmental issues as all aspects of the production, processing, and use of coal come under stricter regulation.

Like coal mining, continuing productivity increases are expected to cause employment in the metal mining industry to decline through 2008. The metal mining industry produces iron ore and ferroalloy ores, such as manganese, tungsten, cobalt, and molybdenum; copper ores; and lead; zinc; gold; silver; aluminum; and uranium, as well as other ores. These materials are used mainly to produce primary nonferrous metals, steel, and industrial chemicals. Metals, such as copper and gold, for example, are used throughout the economy in products such as wire or electrical connectors and contact pads, which are vital to the communications and electronics industries. Nonresidential construction also consumes a large portion of the output of metal mining, as do the automotive and appliance industries. The ability of U.S. mines to remain internationally competitive will influence the long-term outlook. Currently, U.S. mines are among the most technologically advanced in the world; however, mining operations in other countries have lower labor costs and are subject to fewer government regulations. In addition, pending reform of the Mining Law of 1872, which involves issues such as access to public lands and the payment of royalties, is of particular concern to this sector of the mining industry. Changes in policies could have significant long term implications; and uncertainty over restrictions, regulations, and the future of this law could serve to focus more exploration and investment opportunities elsewhere.

The nonmetallic mineral industry produces stone such as limestone or granite, gravel, sulfur, and other nonmetallic minerals. These minerals are used to make concrete and agricultural chemicals and as materials in residential, non-residential, and maintenance construction. Production of most nonmetallic minerals rose almost continuously from 1961 to 1994. Although demand for minerals remains strong, technological changes will continue to increase productivity, limiting the need for workers, so employment in this sector of the industry is expected to decline through 2008.

Sources of Additional Information

For additional information about careers and training in the mining and quarrying industry, write to:

- Mine Safety and Health Administration, 4015 Wilson Blvd., Arlington, VA 22203.
  Internet: **http://www.msha.gov**
- National Mining Association, 1130 17th St. NW., Washington, DC 20036. Internet: **http://www.nma.org**
- Society for Mining, Metallurgy and Exploration, Inc., P.O. Box 625002, Littleton, CO 80162.
  Internet: **http://www.smenet.org**

- United Mine Workers of America, 900 15th St. NW., Washington, DC 20005.

Information on the following occupations in mining and quarrying may be found in the 2000-01 *Occupational Outlook Handbook*:

- Blue-collar worker supervisors
- Chemical engineers
- Electrical and electronics engineers
- Electricians
- Geologists, geophysicists, and oceanographers
- Materials engineers
- Mining engineers, including mine safety engineers
- Petroleum engineers
- Surveyors, cartographers, photogrammetrists, and surveying technicians
- Truckdrivers